Radiated Power Calculations for Open TEM-Waveguides

Application of Transmission-Line Super Theory to a Wire Based System

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***Abstract*— Open wire based TEM-waveguides can mathematically be described by an advanced transmission-line theory which involves intrinsically radiation effects. The radiated power is calculated directly from the complex, position and frequency dependent parameter matrix and the potential and current distribution on the wires. The calculated radiated power is compared to emission measurements in a reverberation chamber and good agreement is achieved.**

TEM-Waveguide; Advanced Transmission-Line Theory; Electromagnetic Radiation

I. INTRODUCTION

TEM-waveguides are widely accepted for qualification testing in EMC. They provide a dominant TEM electromagnetic wave in the designated test volume. Closed TEM-waveguides, as for example GTEM cells, intrinsically produce higher order field modes above cut-off frequencies. This modal behavior can be analytically described by generalized, but classical multi-conductor transmission-line theory. For open TEM-waveguides radiated electromagnetic energy must be taken into account. Therefore, it is necessary to use an advanced transmission-line theory to describe the electromagnetic field in the waveguide and the radiated power. For a conical wire based TEM-waveguide (like a NEMP simulator) Transmission-Line Super Theory (TLST) was used to calculate the radiated power [1]. For this case the TEM-waveguide can be handled as a nonuniform multi-conductor transmission-line. The theoretical results were compared to power emission measurements in a reverberation chamber.

II. TRANSMISSION-LINE SUPER THEORY

TLST [2] is a full wave description of Maxwell's equations cast into the form of telegrapher's equations of classical transmission-line theory.

$$\frac{\partial}{\partial\zeta}\begin{bmatrix}\varphi(\zeta,f)\\ \mathbf{i}(\zeta,f)\end{bmatrix}+j\omega\overline{\mathbf{P}}^{*(1)}(\zeta,f)\begin{bmatrix}\varphi(\zeta,f)\\ \mathbf{i}(\zeta,f)\end{bmatrix}=\begin{bmatrix}\mathbf{0}\\ \mathbf{0}\end{bmatrix} \qquad (1)$$

Eq. (1) shows the TLST equation for a nonuniform N-wire system parameterized according a common parameter ζ, describing normalized arc lengths, with excitation only at the ends of the lines. The parameter matrix $\overline{\mathbf{P}}^{*(1)}$ must be evaluated using an iterative process [3]. The matrix elements are now position and frequency dependent complex values. The radiated power can be calculated from the TLST parameter matrix and the potential and current values on the wires of the multi-wire transmission-line system which are available after solving the coupled first order ODE with the appropriate boundary conditions for exciting sources and loads (see Fig. 1).

III. EXPERIMENTAL VALIDATION

Reverberation chambers are very well suited for emission measurements of electronic systems because of their nearly isotropic field distribution. Radiated power measurements on the wire models of an open TEM-waveguide fit very well to the TLST calculations. In our experiments the radiated power calculations using TLST were validated to measurements for the first time [4].

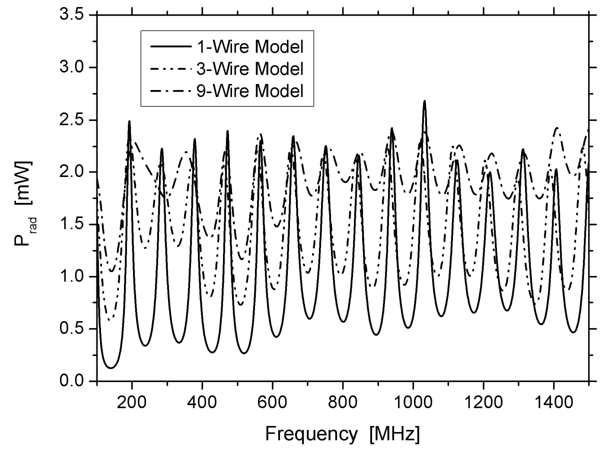

Figure 1. TLST calculated radiated power for open wire based TEM-waveguides made of 1, 3 or 9 wires.

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